THE CHINESE ENVIRONMENTAL POLICY RESEARCH WORKING PAPER

Issue 30 Volume 7 No.1 March 2020

Chinese Academy of Environmental Planning
http://www.caep.org.cn

Action Plans for Air, Water and Soil Pollution Prevention and Control: Investments and Economic-Environmental Impacts

ZHANG Wei, WANG Jinnan, ZHANG Jing, JIANG Hongqiang, LIU Jingwen, WU Qiong

Forword »

Editor in Chief: Prof. WANG Jinnan



Since its opening-up and reform, China has been in the process of rapid economic development with its people enjoying an increasingly improved standard of life. Meanwhile accompanying this dramatic economic growth is the degradation of environment which has, to some extent, damaged the gains of the opening-up and reform and prevented the economy from a healthy and sustainable development. The Chinese government is increasingly aware of that without addressing the environmental issues it is facing now, it will jeopardize its long term goal of the great rejuvenation of the Chinese nation. Given the magnitude and complexity of the environmental issues in China, there is no easy way in addressing them and the solution to them entails an equal priority being given to environmental protection, ecological conservation and economic development or even higher than the latter by mainstreaming the former into the overall socio-economic decision-making process. As a matter of fact, China has been in the struggle against environmental pollution since the very beginning of its economic take-off and trying to explore a pathway that could help address China's environmental issues in the way most suitable to China's specific circumstances.

In recent years, especially since the 12th Five-Year Plan period, the enhanced measures including legislation, policy, regulatory and economic means have been taken by the Chinese government in dealing with environmental problems, of which environmental policies have played an important role in this regard.China has established Xi Jinping's ecological civilization thought, with the concept of green development deeply rooted in the hearts of Chinese people, and now is moving towards the goal of Beautiful China by 2050.

Corresponding to this situation and in meeting the demand of governments at different levels for environmental policy tools, the environmental policy research projects on topics of a wide range have been conducted by some Chinese environmental research institutions including the Chinese

Academy of Environmental Planning (CAEP).

CAEP founded in 2001, is a research advisory body supporting governments in the development of key environmental planning, national environmental policies, and major environmental engineering projects. In the past more than 10 years, CAEP has accomplished the development of the overall planning of national environmental protection for the 10th, 11th, 12th and 13th Five-Year Plan periods; water pollution prevention and control planning for key river basins; air pollution prevention and control planning for key regions; soil pollution prevention and control planning; and some regional environmental protection plans. We are now engaged in national eco-environmental protection plan for the 14th Five-Year Plan. In the same period of time, CAEP also actively engaged in research on such topics as green GDP, environmental taxation, emission trading, ecological compensation, green financing, etc. By undertaking these activities, CAEP has become an indispensable advisory body in the environmental decision-making in mainland China. According to *2019 Global Go To Think Tank Index Report* published by University of Pennsylvania, CAEP was ranked 25 in the field of Environment Policy in the world. Many of CAEP's research results and project outcomes regarding environmental policies have drawn great attention of decision makers and international institutions, and have been utilized to contribute to the formulation of national environmental policies concerned.

The Chinese Environmental Policy Research Working Paper (CEPRWP) is a new internal publication produced by CAEP for the purpose of facilitating the academic exchange with foreign colleagues in this field, in which the selected research papers on environmental policies from CAEP are set out on the irregular basis. It is expected that this publication will not only make CAEP's research results on environmental policies be known by foreign colleagues but also serve as a catalyst for creating opportunity of international cooperation in the field of environmental policies, and environmental economics in particular, with a view of both the academic research and practical policy needs.

This paper is a study on the investments of the three environmental quality improvement action plans and their environmental impacts. To significantly improve environmental quality, the Chinese government issued three action plans for preventing and controlling air, water and soil pollution in 2013, 2015 and 2016, respectively, which requires a huge investment and promotes the development of related industries. Using a closed macro input-output model of China, this study simulated the impact of the three action plans' investments on China's economic growth, and induced resource consumptions and pollutants emissions. The result shows that a total 8.05 trillion CNY is required for three Action Plans, which will lead to 11.16 trillion CNY GDP growth. Moreover, they will stimulate the growth of pollution-intensive and resource-intensive industries through supply chains, which may indirectly bring additional resource consumptions and pollution emissions. Our results can help provide appropriate recommendations for environmental policy-making from the environmental-economic nexus perspective.

Contents

1. BACKGROUND

China's rapid economic growth, boosting urbanization and heavy-industrial development pattern brought serious environmental problems in the past decades[1-4]. In both January and December of 2013, continuous heavy haze affected almost all the central, eastern, and northern areas of China, which attracted world's attentions. Based on the WHO ambient air pollution database, the annual mean PM_{10} in China's provincial capital cities from 2008 to 2010 were all among the highest worldwide, with Beijing ranking 1035th among the 1082 surveyed cities[5]. The annual mean $PM_{2.5}$ in Beijing, Tianjin and Hebei was 106 $\mu g/m^3$ in 2013[6], which was 4 to 6 times higher than cities in developed countries. Meanwhile, water pollution is key threaten to China's water security. By 2014, about 10% of all the national-monitored surface water bodies have lost their functional use, and 24.6% of the major lakes suffer from eutrophication. Among the 4778 underground water monitoring sites, 43.9% were certified as relatively bad and 15.7% were certified as extremely bad. The water qualities in 6 of the 9 major gulfs were ranked as bad or extremely bad[7]. Soil pollution is also serious. Previous estimations suggest that up to 20% of China's agricultural soil has been contaminated by heavy metals [8]. According to the latest findings of the national survey on soil quality, 16.1% of all samples taken nationwide exceeded healthy levels of metal pollution, with 19.4% of samples taken from agricultural areas exceeding the standards, where the main pollutants were Cd, Ni, Cu, As, Hg, Pb, DDT and PAHs[9]. Over the last few decades, many surveys have been carried out in China, which showed that agricultural soil in China was suffering from heavy metal pollution [10].

Given the severe air, water and soil pollution situations, the Chinese central government issued the Action Plans for Preventing and Controlling Air (Air Plan I), Water and Soil Pollution (Water Plan, Soil Plan) in 2013, 2015 and 2016 respectively. The year 2017 marked the end of the first phase of the 'Air Plan I', whose mission targets were fundamentally achieved throughout the country. Thus, the State Council issued a Three-Year Plan on Defending The Blue Sky (Air Plan II) in June 2018. All three action plans will last until 2020. The three action plans serve as the guiding principles and roadmaps for China to deal with major environmental problems in the foreseeable future.

The implementation of the three action plans requires a huge investment, which aims to improve China's environment quality, but also promotes the development of pollution control-related sectors, boosting the macroeconomic system through the upstream and downstream supply chains [11,12]. Therefore, a scientific evaluation of the social and economic impact of three action plans can assist industrial planners and environmental practitioners in scientific decision making. Meanwhile, during the three

action plans, rising demands for products and services (such as power and steel) will inevitably lead to the use of more natural resources and generate pollutants, which poses environmental issues [13]. Therefore, the impact of the three action plans on the emission of pollutants should also be scientifically evaluated.

In this study, a closed macro input-output model mapping the spillover and linkage effects of industrial and residential consumption was established to quantitatively evaluate the impacts of the three action plans on China's economy. Meanwhile, the impact of the three action plans on employment within different sectors was also quantitatively simulated.

2. BRIEF INTRODUCTION OF THE THREE ACTION PLANS

2.1 Action Plan for Air Pollution Prevention and Control, 2013-2017, 2018-2020

2.1.1 Air Plan I, 2013-2017

Air Plan I aims to improve the overall national air quality in five years with specific reduction goals for key pollutants. The targets are:

- By 2017, the urban concentration of Particulate Matters (PM_{10}) shall decrease by 10% compared with 2012;
- Annual number of days with fairly good air quality will gradually increase;
- Concentration of fine particulate matter ($PM_{2.5}$) in Beijing-Tianjin-Hebei, Yangtze River Delta and Pearl River Delta region shall respectively fall by around 25%, 20% and 15%;
- Fine particulate matter annual concentration in Beijing shall be controlled below 60 micrograms per cubic meter.

The action plan proposed ten measures to achieve the targets: (1) increase efforts of comprehensive control and reduce emission of multiple pollutants; (2) optimize the industrial structure and promote industrial upgrading; (3) accelerate technology transformation and improve innovation capability; (4) adjust energy structure and increase clean energy supply; (5) strengthen environmental thresholds and optimize industrial layout; (6) better play the role of market mechanism and improve environmental economic policies; (7) improve the legislation and regulation system; (8) establish regional coordination mechanism and integrated regional environmental management system; (9) establish monitoring and warning system; (10) clarify the responsibilities of the government, enterprise and society, and mobilize public to participate in environmental protection.

2.1.2 Air Plan II, 2018-2020

The State Council has released a three-year plan here we called the second Air Pollution Action Plan. The plan will help China make significant improvements to air quality and people's satisfaction by reducing emissions quantities of major air pollutants and greenhouse gases, reinforcing control of $PM_{2.5}$ density and decreasing the number of seriously polluted days for key regions.

- According to the plan, sulfur dioxide and ammonia oxides emissions in 2020 will decrease to no more than 85% compared with 2015. The new plan matches the $PM_{2.5}$ target published in 2016 as part of the 13th Five-Year Plan for environmental protection:

mandating falls of at least 18% in $PM_{2.5}$ levels on a 2015 baseline in cities of prefectural or higher level, and where standards have not already been met. Annual number of days with fairly good air quality should reach up to 80% a year and annual number ratio of days with severe pollution will fall of at least 25% of the year 2015.

- Consolidate the achievements for cities which fulfilled ahead provincial objectives and tasks of the"13th Five-Year Plan"
- Comprehensively realize the binding targets of the "13th Five-Year Plan" for substandard cities
- Further improve Beijing's Environmental and air quality targets on the baseline of the "13th Five-Year Plan"

Compare to the expired Air Pollution Action Plan, targets of the new plan concentrate on regions suffering severe air quality and most serious excessive Fine Particular Matters ($PM_{2.5}$) problems. The Fenhe and Weihe plains come under the new plan action as their severe pollution, replacing the Pearl River Delta which completely accomplished former action plan. Meanwhile, the key region of the second phase action plan expands the scope of the Beijing-Tianjin-Hebei agglomeration as Beijing-Tianjin-Hebei and surrounding areas. To achieve the goals, the State Council urged authorities to adjust industrial structures, promote sustainable development, rectify the energy structure for clean energy supply, adjust transportation systems to advance green transport, and enhance pollution management by optimizing land use systems. In addition, it called on efforts to carry out major action plans and activities to reduce pollution, coordinate prevention and control to cope with heavily polluted days, and improve laws, regulations and policies. Authorities also should build infrastructure capacities and strengthen law enforcement, while clearly assigning responsibilities and engaging the public in protecting the environment.

2.2 Action Plan for Water Pollution Prevention and Control, 2015-2020-2030

The water pollution control plan incorporates both qualitative and quantitative goals to promote the overall water quality in various regions, along with clear timelines, detailed measures, and specific task distribution plans. The overall objectives are:

- By 2020, China's water quality shall be gradually improved;
- To greatly reduce the percentage of badly polluted water bodies – over 70% of the water in 7 key rivers shall reach Grade III or above;
- To improve the quality of drinking water – over 93% of urban drinking water sources shall reach Grade III or above;
- To reduce groundwater over

extraction and control groundwater pollution – groundwater falling under "very bad" category shall decrease to around 15%;

- To improve the environmental quality of coastal areas – up to 70% of coastal water shall reach Grade I or II;
- Improve urban water environment in key regions – the amount of Grade V+ water in Beijing-Tianjin-Hebei shall fall by 15%, and Grade V+ water shall be eliminated in Yangtze River Delta and Pearl River Delta;
- By 2030, the overall quality of the ecology and environment will be improved;
- By the middle of the 21st century, the quality of the ecology and environment should be fully improved and the ecosystem should realize a virtuous cycle.

Ten measures were proposed to achieve the goals: (1) overall control of pollutant discharge; (2) promote the transformation and upgrade of economic structure; (3) water saving and conservation; (4) strengthen science and technological support; (5) fully play the role of market mechanism; (6) tighten the enforcement and supervision of environmental laws; (7) strengthen water management system; (8) thoroughly guarantee the safety of water ecological environment; (9) define and fulfill the duty of each department; (10) enhance public participation and social supervision.

2.3 Action Plan for Soil Pollution Prevention and Control, 2016-2020-2030

The core of the plan is to improve the soil quality with a comprehensively controlled risk. It focuses on ensuring the safety of the agricultural product and human living environment. The overall objectives are:

- By 2020, it's expected to curb the nation's increasing soil pollution, achieve a sound and stable soil environment quality, ensure a safe soil environment for agricultural land and land used for construction purposes, and basically control the soil environmental risks.
- By 2020, the proportion of contaminated farmland that can be used safely is expected to be 90% around, and that of contaminated sites expected to be above 90%.
- By 2030, it's expected that the nations' soil environment quality will be steadily improved, the soil environment safety of farmland and land used for construction purposes effectively guaranteed, and the environmental risks of soil thoroughly controlled.
- By 2030, the proportion of contaminated farmland that can be used safely will increase to 95%,

and that of contaminated sites to above 95%.

- By the middle of this century, the soil environment quality will be improved comprehensively, and a virtuous cycle of the ecological system will be achieved.

Ten special measures have been drafted alongside the Soil Plan to ensure the fulfillment of these targets: (1) conduct survey on soil pollution, and get a better understanding of the baseline of soil environment quality; (2) promote Legislation of Soil Pollution Control, Establish Sound Regulation and Standard System; (3) manage agricultural land by categories to ensure a safe environment for agricultural production; (4) implement the access management for construction land, guard against the risk of livelihood environment; (5) strengthen the protection of soil that is not polluted, strictly control the pollution of new soil; (6) strengthen the regulation on pollution sources and emphasize the soil pollution prevention and control; (7) conduct pollution treatment and remediation, improve regional soil environment quality; (8) increase efforts on technological research and development, advance the progress of environmental protection industries; (9) give full play to the dominant role of government and develop a soil environmental governance system; (10) strengthen objective assessment and accountability

2.4 Summary

The above Action Plans, mainly focusing on prevention of atmosphere, water and soil, are a series of prevention actions and essence indicative planning which also cover relevant environmental resources. Implication of the plans is complicated that though they could cause gigantic labor, material and money, the ultimate benefits brought to the environment, economic and society are appreciable. This report simulates the environmental-economic impacts of three Action Plans during the implementing period.

3. ECONOMIC IMPACTS OF THREE ACTION PLANS

3.1 Economic impacts of Air Plan

3.1.1 Air Plan I

(1) Investment demand

The achieving of the emission reduction targets of the Air Plan I requires eight measures, with total estimated investment demand of 1.7475 trillion CNY. As is shown in Table 1, four major measures, including industrial pollution control, clean energy replacement, motor vehicle pollution control, and strengthening of the central heating system, account for 88.78% of the total investment demand [13].

Table 1. Investment demand of the Air Plan I

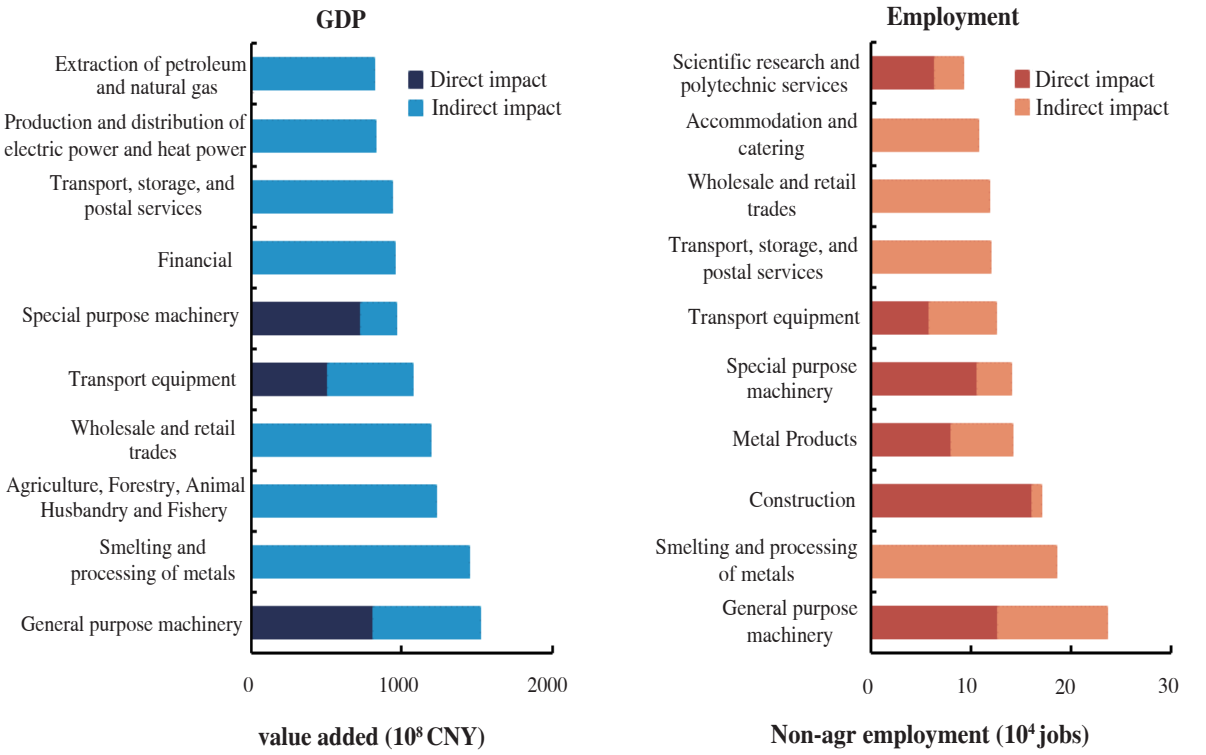
Measures	Main contents	Investment (billion CNY)
Industrial pollution control	Construction and upgrade of desulfurization, denitrification, and dust removal facilities; transformation of coating lines; and modification of gas equipment.	640.9
Clean energy replacement	Transform coal facilities into gas facilities in self-owned power plants and coal-fired boilers; build urban gas pipeline network.	493.0
Motor vehicle pollution control	Develop renewable energy automobiles, upgrade gas quality, and cancel subsidies for yellow-label cars.	210.0
Strengthen central heating system	Construct urban central heating system, and modify the heating system of urban villages.	207.5
Operational costs	Operational costs of pollution control facilities	85.0
Non-point source pollution control	Comprehensive dust control of construction sites and material fields.	60.5
Capacity building	Capacity building of environmental monitoring and supervision	27.0
Clean use of coal	Construction of coal blending and washing facilities.	23.6
Total		1747.5

(2) Economic impacts

The implementation of the Air Plan I from 2012 to 2017 may altogether contribute 2.057 trillion CNY to the national GDP, which equals 3.2% of the GDP in 2014. Industries benefits most included: *Manufacture of general purpose machinery, Smelting and processing of metals, Agriculture, Forestry, Animal Husbandry and Fishery, Wholesale and retail trades, Manufacture of transport equipment, Manufacture of special purpose machinery, Finance, Transport, storage, and postal services, Production and distribution of electric power and heat power, and Extraction of petroleum and natural gas*. The net increase of value added of above industries is estimated to reach 1.091 trillion CNY, accounting for 53% of the total increase. The Air Plan I directly impact industries in *Manufacture of general*

purpose machinery, Manufacture of transport equipment and *Manufacture of special purpose machinery*. The indirect effected industries included *Processing of petroleum, coking, processing of nuclear fuel, Transport, storage, and postal services, Wholesale and retail trades, Agriculture, Forestry, Animal Husbandry and Fishery,* etc [13].

Figure 1. Top ten sectors with the highest increase of value added and employment during Air Plan I



Same study demonstrates that the Air Plan I will create 2.6 million non-agricultural jobs after five years of implementation, which means that every investment of 670,000 CNY will create 1 non-agricultural job. New jobs created in the ten industries shown in Figure 1. The sectors that will directly be affected by the Air Plan I are *Manufacture of general purpose machinery, Construction, Manufacture of metal products, Manufacture of special purpose machinery, Manufacture of transport equipment,* and *Scientific research and polytechnic services.*

3.1.2 Air Plan II

(1) Investment demand

The Air Plan II implementation process consists of 9 measures to control air pollution. It is estimated that a total of 759.3 billion CNY investment is needed.

Table 2. Investment of the Air Plan II

Measures	Detailed information	Amount (billion CNY)
Scattered dirt disposal	Increase investment and maintenance fee for factories resolve scattered and dirt problems	38.2
Electric and natural gas substitution for coal chuck	Cost of replacing coal chunk to electricity and natural gas, mainly consist of heating equipment investment fee, infrastructure fee and annual operating subsidy	249.4
Coal fired boiler cleaning	Eliminate inefficient small coal-fire boiler	8.8
Industrial pollution control	Pollution control for key industries, industry kiln stove and VOC	242.7
Improve oil quality	Cost of oil upgrade	95.9
Construction of power facilities on the river bank	Including the cost of major coastal ports berth reconstruction, the cost of building new port terminals and airport shore power facilities, and the cost of ship power facilities refurbishment.	5.5
Motor vehicle pollution control	Subsidies for yellow label cars (heavy-polluting vehicles), expired vehicles elimination cost; Subsidies for clean energy vehicles; cost of pollution control for heavy diesel trucks.	37.4
Non-point source pollution control	Control construction dust, road dust and forbid stalk burning	54.0
Capacity building	Air quality monitor, technical support, set up automatic system and enforcement supervisor for VOCs key emission source system.	27.4
Total		759.3

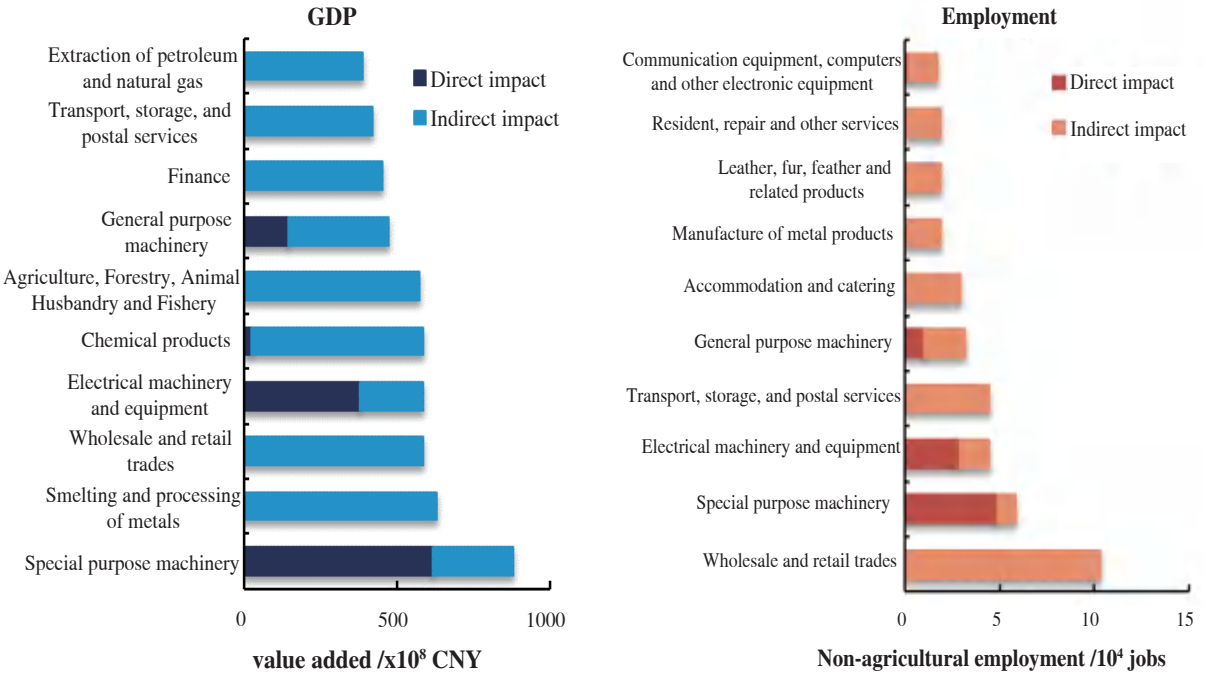
(2) Economic impacts

The above investments are predicted to drive a GDP growth of approximately 946.2 billion CNY, 140 billion of residents' income increase and 600,000 non-agricultural jobs. Input-output ratio of GDP is 1.24, which means that every 10,000 CNY investment spent in the implementation of Air Plan II will increase 12,400 CNY GDP growth [14].

Main beneficiary industries in Air Plan II investments include *Manufacture of special purpose machinery, Smelting and processing of metals, Wholesale and retail trade, Manufacture of electrical machinery and equipment, Manufacture of chemical products, Agriculture, Forestry, Animal Husbandry and Fishery, Manufacture of general purpose machinery, Finance, Transport, storage, and postal services, Extraction of petroleum and natural gas,* etc.. The total added value of above industries are about 555 billion CNY, accounted for 58.7% of all net value added. The industries directly affected by Air Plan II are mainly concentrated in *Manufacture of general purpose machinery, Manufacture of transport equipment, Manufacture of special purpose machinery, Manufacture of electrical machinery and equipment* and other industries. Moreover, industry association and consumption lead to indirectly affect by

the "Air Plan II" are mainly concentrated in the basic industries of the national economy and productive services, which are basically the same as those in Air Plan I.

Figure 2. Top ten sectors with the highest increase of value added and employment (Air Plan II)



The implementation of the Air Plan II project will cumulatively increase non-agricultural employment by 60×10^4, which means every 126×10^4 CNY investment in the action will provide 1 non-agricultural job. From the perspective of beneficial industries, the implementation of the Air Plan II will enable 10 major industries including *Wholesale and retail trades, Manufacture of special purpose machinery, Manufacture of electrical machinery and equipment, Transport, storage, and postal services, Manufacture of general purpose machinery, Accommodation and catering, Manufacture of metal products, Manufacture of leather, fur, feather and related products, Resident, repair and other services, Manufacture of communication equipment, computers and other electronic equipment*. Total non-agricultural employment in the above industries increased to 38×10^4, accounted for 63.7% of new non-agricultural jobs. Among the newly-added non-agricultural jobs, industries directly affected by Air Plan II are mainly concentrated in *Manufacture of special purpose machinery, Manufacture of electrical machinery and equipment, Manufacture of general purpose machinery, Construction,*

etc. In addition, the implementation of the action will indirectly increase non-agricultural employment in *Wholesale and retail trades, Manufacture of special purpose machinery, Manufacture of electrical machinery and equipment, Transport, storage, and postal services, Manufacture of general purpose machinery, Accommodation and catering* industry through industrial associations.

3.2 Economic impacts of Water Plan

(1) Investment demand

The Water Plan proposed 238 specific measures to achieve the goal of improving water quality. It is estimated that a total of 4.5 trillion CNY is needed to invest in eight aspects, as is shown in Table 3[15].

Table 3. Investment of the Water Plan

Measures	Major contents
Industrial pollution control	Pollutant source treatment, backward production capacity elimination, industrial restructuring, pollution control of key industries and industrial parks, etc.
Urban household pollution control	Sewage treatment facilities construction, network construction, sludge treatment and disposal subsidies guidance, rainwater and sewage diversion pipe network leakage maintenance, etc.
Rural and agricultural pollution control	Large-scale livestock and poultry breeding pollution prevention and control, comprehensive improvement of rural environment, etc.
Ship port pollution control	Construction of pollution control facilities.
Reuse of municipal wastewater	Construction of urban wastewater reusing equipment.
Capacity building of environmental monitoring	All index monitoring, water monitoring network, water source to water tap monitoring and information disclosure, monitoring evaluation of water carrying capacity.
Integrated treatment of the environment	Urban black and odor water treatment, water source protection, ecological restoration, garbage cleaning, etc.
Water saving and protection	Water saving facilities in key industries, agricultural water saving projects, water saving appliances promoting, urban water supply network reconstruction.
Investment demand	4.5 trillion CNY

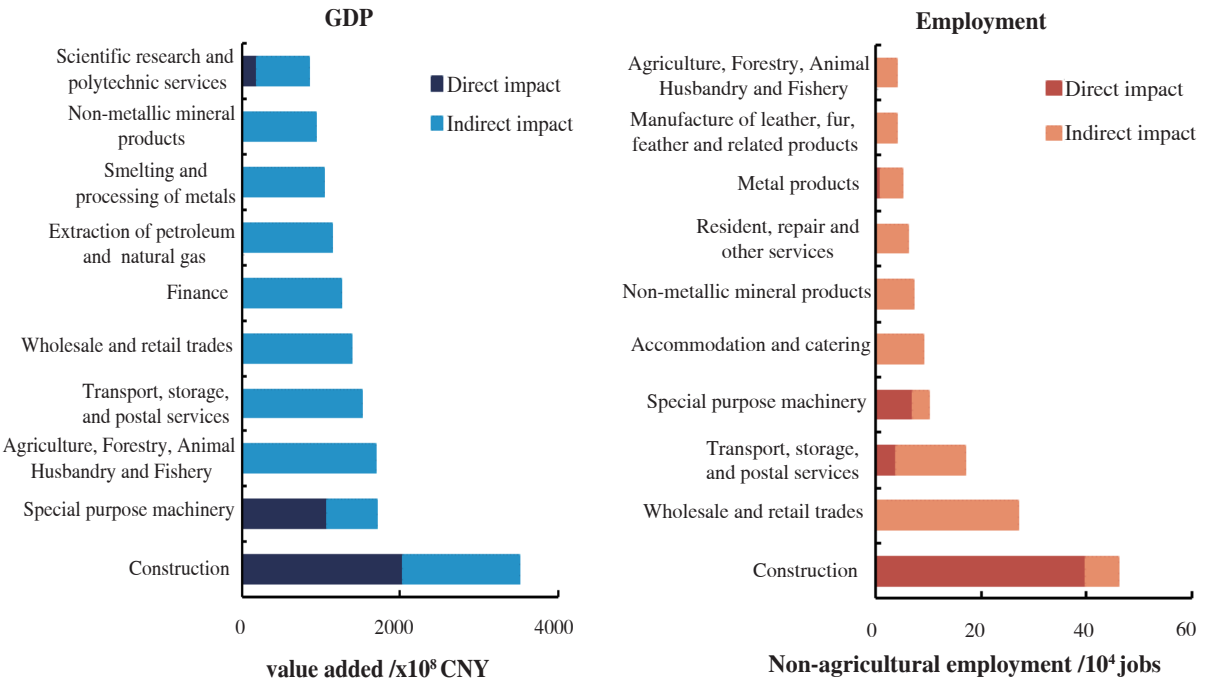
(2) Economic impacts

The implementation of Water Plan from 2015 to 2020 is expected to generate a net increase of 5.696 trillion CNY for the national GDP, which equals 8.96% of the GDP in 2014. About 13% of the total increase will be directly contributed to the economy, and 87% are results of indirect stimulation to relevant industries [15].

Figure 3 shows the ten sectors that will enjoy the highest increase in value added because of the implementation of Water Plan. The overall contribution of the ten sectors is estimated to reach 3.218 trillion CNY,

accounted for 57% of total GDP growth. 10 industries are benefited from the Water Plan, including *Transport, storage, and postal services, Wholesale and retail trades, Agriculture, Forestry, Animal Husbandry and Fishery, Finance, Manufacture of special purpose machinery, Manufacture of non-metallic mineral products, Extraction of petroleum and natural gas, Scientific research and polytechnic services, Smelting and processing of metals, construction.* Among these beneficial industries, *Construction, Manufacture of special purpose machinery, Scientific research and polytechnic services* and some others are directly affected by the Water Plan investment; while *Agriculture, Forestry, Animal Husbandry and Fishery, Wholesale and retail trades, Finance, Extraction of petroleum and natural gas* and basic industries of the national economy, such as the metal mineral products industry and the power production industry, are dominated by indirect effects of investment.

Figure 3 Top ten sectors with the highest increase of value added and employment (Water Plan)



The study also shows that the implementation of Water Plan will create almost four million non-agricultural jobs in six years, meaning that every 1,000,000 CNY investment will create one job (Figure 3). The beneficial industries mainly including *construction, wholesale and retail, transportation and storage, accommodation and catering,*

special equipment manufacturing, non-metallic mineral products, residential services and other services, metal products, general equipment manufacturing, textiles, clothing, footwear and hat manufacturing, etc. This will contribute 275 million employment which accounted for 69% of total employment growth. Among 10 beneficial industries, *the construction industry, special equipment manufacturing industry and comprehensive technical service industry* are directly affected by Water Plan. While labor-intensive industries including wholesale and retail, transportation and storage, accommodation and catering, and residential services or basic service industries are obviously indirectly affected.

3.3 Economic impacts of Soil Plan

(1) Investment demand

Investment data for the Soil Plan was taken from the *Table of Funding Estimates for the Soil Plan.* As shown in Table 4, the Soil Plan's investment will be categorized into four main fields, namely, fundamental capacity building, soil pollution risk management and control, soil pollution treatment and remediation, and soil pollution source control. A total of CNY 1.14 trillion will be invested during the period of 2016-2020[16].

Table 4. Investment of the Soil Plan

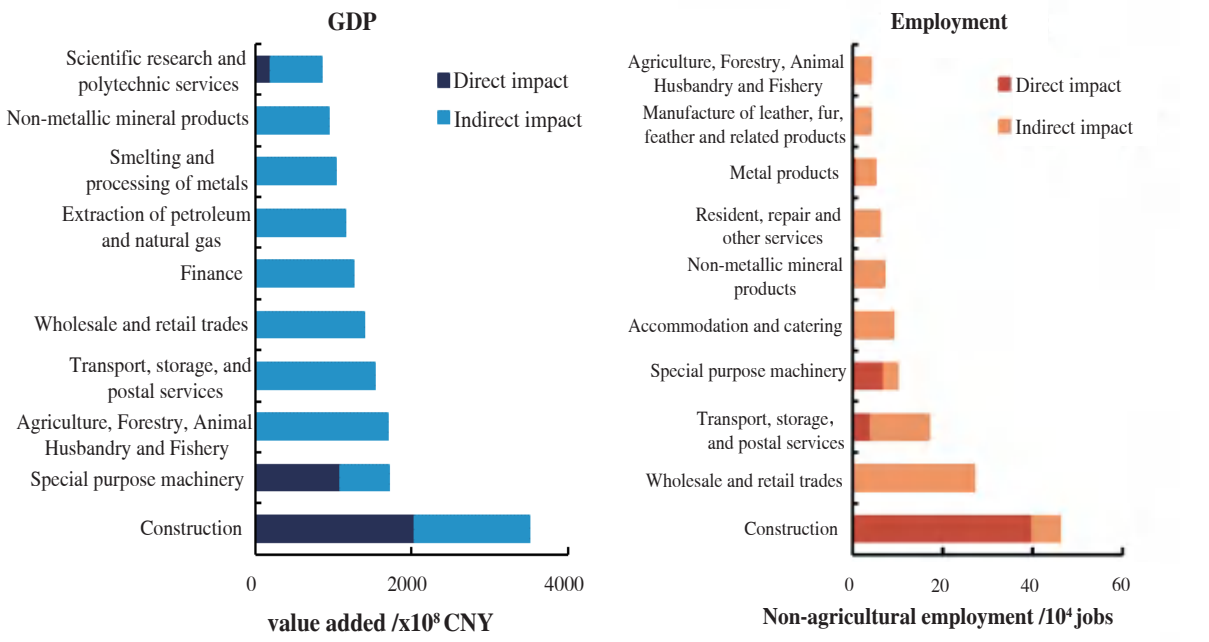
Aspects	Details	Investments (billion CNY)
Fundamental capacity building	A detailed survey on soil pollution; revision of laws, regulations, relevant standards and technical specifications; capacity building for soil monitoring and law enforcement; construction of soil pollution control laboratories and engineering technology centers	72.5
Risk management & control	Safe utilization measures (agricultural regulation, alternative planting, etc. for slightly polluted farmland); risk control measures (planting structure adjustment, returning farmland to forest or grassland, etc.) for seriously polluted farmland; barrier and enclosure, etc. for contaminated sites	321.0
Pollution treatment & remediation	Pilot and demonstration of pollution management and remediation; construction of pilot areas of soil pollution management; management and remediation of contaminated farmland	179.0
Pollution source control	Heavy metal pollution prevention and remediation; comprehensive control and treatment of tailings ponds, solid waste dumps and informal landfills; construction of pilot areas for collaborative control and treatment	569.5
Total	—	1142.0

(2) Economic impacts

As shown in Figure 4 GDP, the 1142 billion CNY investments in the Soil Plan would help increase China's GDP by 2716 billion CNY over five years (2016 to 2020) - direct and indirect contributions making up 358.11 billion CNY and 2358 billion CNY, respectively. The input-output ratio of

investment in the Soil Plan is 1:2.38, which means that each CNY investment of Soil Plan would induce the GDP by 2.38 CNY. The ten main sectors that benefit from the investment of Soil Plan include *Construction, Agriculture/forestry/animal husbandry/fishery, Transportation and warehousing, Wholesale and retail, Special-purpose equipment manufacturing, Finance, Oil and natural gas mining, Black metal smelting and rolling processing, Non-metal mineral products,* as well as *Comprehensive technical services*. The induced GDP of these ten sectors is 1500 billion CNY, which accounts for 55% of the total induced GDP by the investment of Soil Plan. The GDP growth of the *Construction* and *Special-purpose equipment manufacturing* will be a direct contribution of the investment during the Soil Plan, whereas the growth of some basic sectors of the national economy - such as the *Agriculture, forestry, animal husbandry and fishing,* and *Transportation and warehousing,* will only be indirectly attributable to Soil Plan investments through industrial supply chains[16].

Figure 4. Top ten sectors with the highest increase of value added and employment (Soil Plan)



As shown in Figure 4 Employment, 198×10^4 new jobs would be created over five years during the implementation of the Soil Plan. Among them, 62×10^4 jobs (31%) would be attributable to direct contribution, while 137×10^4 (69%) jobs would be created indirectly. The ten main sectors to benefit from the Soil Plan's investments would include *Construction, Wholesale and retail trades, Transport, storage, and postal services, Manufacture of special purpose*

machinery, Accommodation and catering, Manufacture of non -metallic mineral products, Resident, repair and other services, Manufacture of metal products, Manufacture of leather, fur, feather and related products, and Agriculture, Forestry, Animal Husbandry and Fishery. These sectors alone would see the creation of 63×10^4 new jobs, accounting for 32% of total figures. The new jobs created for sectors such as *Construction* and *Manufacture of special purpose machinery* would result from direct contribution, whilst the jobs created in other less labor-intensive sectors, such as the *Wholesale and retail trades, Accommodation and catering,* and *Resident, repair and other services,* would be categorized as an indirect contribution.

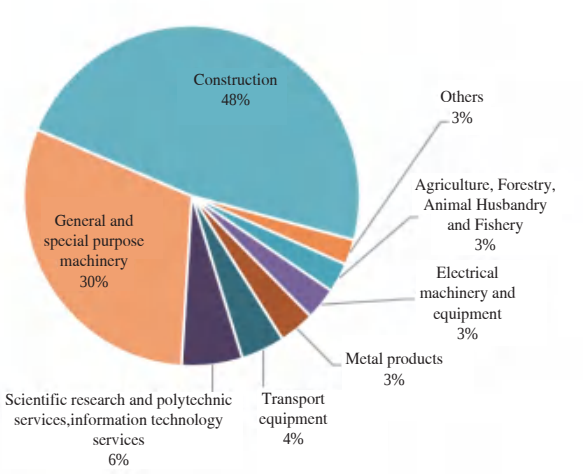
3.4 Summary

(1) Investment

According to investment demand, total investment of three Plans are 8150 billion CNY, of which Air Plan accounts for 29.9%, Water Plan accounts for 55.9%, and soil plan accounts for 14.2%.

Figure 5 illustrates the breakdown of investment demand into sectors. The major sectors are: *Manufacture of general and special purpose equipment, Construction, Scientific research and polytechnic services, Information transfer, software and information technology services, Manufacture of transport equipment, Manufacture of metal products, Manufacture of electrical machinery and equipment, Agriculture, Forestry, Animal Husbandry and Fishery* and others, which proportion of general and special-purpose manufacture equipment industries are up to 78%. The purchase of *Manufacture of general and special-purpose equipment* requires the most investment, which includes general equipment such as heating facilities, gas boilers, petrochemical metallurgy equipment, and coal washing equipment, and purchase of equipment solely for environmental protection, e.g., rapid monitoring equipment for contaminated land, desulfurization and denitration facilities, etc.

Figure 5. Investment demand to achieve three Action Plans by sector

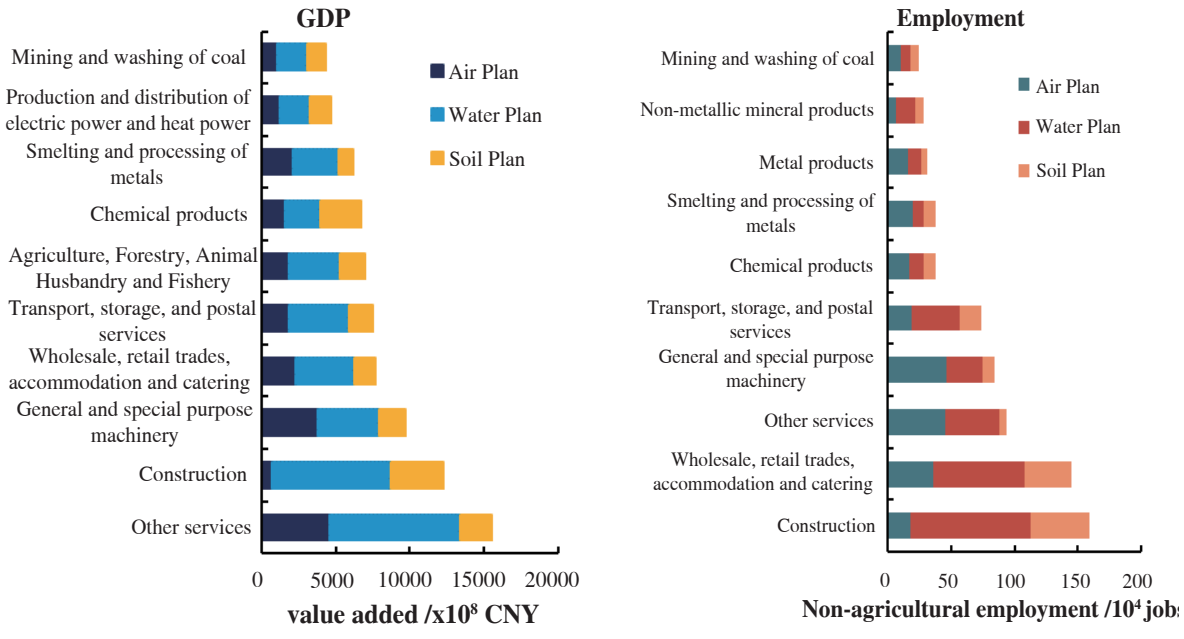


(2) Economic impacts

According to the economic data above, implementation of the three plans will stimulate GDP growth by 11,156 billion CNY, which Air Plan accounted for 26.3%, Water Plan accounted for 49.9%, and Soil Plan accounted for 23.8%. The total implementation budget input-output ratio of the three plans is 1.40 million CNY, that is, every investment of 10,000 CNY will

raise 1.4 million CNY GDP growth. Figure 6 shows the total economic impact of the three plans. In summary, *Other services (including Information transfer, software and information technology services, Finance, Real estate, Leasing and commercial services, Scientific research and polytechnic services, Administration of water, environment, and public facilities, Resident, repair and other services, Education, Health care and social work, Culture, sports, and entertainment, Public administration, social insurance, and social organizations), Construction, Manufacture of general and special purpose machinery, Wholesale, retail trades, accommodation and catering, Transport, storage, and postal services, Agriculture, Forestry, Animal Husbandry and Fishery, Manufacture of chemical products, Smelting and processing of metals, Production and distribution of electric power and heat power, Mining and washing of coal* are ten industries that mostly affected by the investment. Total added value of the ten industries are 8.13 trillion CNY, in which other service industry raising up to 1.55 trillion CNY and construction industry increasing to 1.22 trillion, compared with 3.29 trillion CNY in others. Industries including construction, general and special purpose machinery and other services contribute the largest GDP growth in direct effect and other services, wholesale, retail trades, accommodation and catering, transport, storage, and postal service contribute most in indirect effect.

Figure 6. Ten sectors with the highest increase of value added and employment



According to the employment data above, implementation of the three plans will stimulate employment growth by 9.8 million positions, which Air Plan accounted for 34.9%, Water Plan accounted for 43.4%, and Soil Plan accounted for 21.8%. Every investment of 88×10^4 CNY will create 1 job. *Construction, Wholesale, retail trades, accommodation and catering, Other services, Manufacture of general and special purpose machinery, Transport, storage, and postal services, Manufacture of Chemical products, Smelting and processing of metals, Manufacture of metal products, Manufacture of non -metallic mineral products, Mining and washing of coal* are the most involved industries, which boost employment by 714.07 million, 77.8% of total.

4.POTENTIAL RESOURCE AND ENVIRONMENTAL IMPACT OF THREE ACTION PLANS

4.1 The impacts of the Air Plan on resource and environment

4.1.1 Air Plan I

(1) Energy and Water

The implementation of the Plan requires resource consumption. Results show that during the implementation period, the coal and water consumption will increase to 1.6 × 10^8 and 108.2 × 10^8 t, respectively, and the average annual increase in consumptions of these two resources will be in same amount of 1.34% and 0.36% in 2010. Potential coal consumption and water consumption are mainly concentrated in the *Production and distribution of electric power and heat power, Smelting and processing of metals, Manufacture of non -metallic mineral products,* and *Manufacture of special purpose machinery* (Table 5), which together accounted for 95% and 76% of the increased consumption in water and coal[13].

Table 5. The top five sectors of potential resource consumption (Air Plan I)

Sectors	Coal /10^4 t	Sectors	Fresh Water /10^8 t
Production and distribution of electric power and heat power	12 989.6	Production and distribution of electric power and heat power	61.1
Smelting and processing of metals	1 060.1	Smelting and processing of metals	8.3
Manufacture of non -metallic mineral products	849.9	Manufacture of chemical products	5.8
Manufacture of chemical products	555.7	Mining and processing of metal ores	4.3
Manufacture of special purpose machinery	94.4	Mining and washing of coal	2.3
Total	15 549.8	Total	81.7

(2) Main pollutants emissions

During the implementation period, the Air Plan stimulates the boosting of relevant industries, which also causes pollution emissions indirectly. Results show that cumulative additional emission of SO_2 and NO_x will be 121.3 × 10^4t and 96.0 × 10^4t, the annual increases of SO_2 and NO_x emissions are equivalent to 3.8% and 2.2% of the expected reduction capacity. SO_2 and NO_x emission reduction capacities are 641 × 10^4 and 869 × 10^4t respectively. Potential air pollutant emission in industries are mainly concentrated in the *Production and distribution of electric power and heat power, Smelting and processing of metals, Manufacture of non -metallic mineral products,* and *Manufacture of special purpose machinery, Processing of*

petroleum, coking, processing of nuclear fuel (see Figure 7), which together accounted for 92% and 94% of the additional SO_2 and NO_x emissions, respectively. Meanwhile, industries also discharging water pollutants like16.9 × 10^4 t COD emissions and 1.2 × 10^4t NH_3-N emissions.

Figure 7. Emission of four main pollutants by sector (Air Plan I)

4.1.2 Air Plan II

(1) Energy and Water

Results show that during the period of implementation of Air Plan II, the potential coal and water consumption will increase to 7333.2×10^4 t and 49.3×10^8 t, respectively, and the average annual increase of above resources will amount 0.52% and 0.27% of the total national consumptions in 2018. Potential coal consumption and water consumption are mainly concentrated in *electric heating production and supply industry, metal smelting and rolling industry, other chemical industry, non-metallic mineral products industry, special equipment manufacturing industry,* which together accounted for 95% and 76% of the increased consumption in water and coal [13].

Table 6. The top five sectors of potential resource consumption (Air Plan II)

Sectors	Coal/10^4 t	Sectors	Fresh Water/10^8 t
Production and distribution of electric power and heat power	5800.6	Production and distribution of electric power and heat power	27.3
Smelting and processing of metals	463.2	Smelting and processing of metals	3.6
Manufacture of chemical products	312.4	Manufacture of chemical products	3.3
Manufacture of non -metallic mineral products	288.6	Manufacture of non -metallic mineral products	1.8
Manufacture of special purpose machinery	86.3	Manufacture of special purpose machinery	1.3
Total	6951.0	Total	37.3

(2) Main pollutants emissions

During the implementation of Air Plan II, the cumulative additional emissions of SO_2, NO_x, COD, and NH_3-N were 54.4×10^4 t, 43.0×10^4 t, 8.4×10^4 t, and 0.6×10^4 t. The potential air pollutant emission industries are mainly concentrated *Production and distribution of electric power and heat power, Smelting and processing of metals, Manufacture of chemical products, Manufacture of non-metallic mineral products and Processing of petroleum, coking, processing of nuclear fuel,* etc., together accounted for 90% and 94% of the additional emissions of SO_2 and NO_x respectively. Potential water pollutants mainly concentrated in *Manufacture of paper, printing and articles for culture, education and sport activity, Manufacture of chemical products, Food and tobacco processing, Smelting and processing of metals.*

Figure 8. Emission of four main pollutants by sector (Air Plan II)

4.2 The impacts of the Water Plan on resource and environment

(1) Energy and Water

During the implementation of Water Plan, the additional coal and water consumption will be 4.2×10^8 t and 209.9×10^8 t, respectively. The average annual consumption of two are equivalent to 1.72% and 0.77% of the amount in 2015. Potential coal and water

consumption are mainly concentrated on *Production and distribution of electric power and heat power, Manufacture of non -metallic mineral products, Smelting and processing of metals, Manufacture of chemical products, Construction* (see Table 7), which together accounted for 95% and 74% of coal and water consumption.

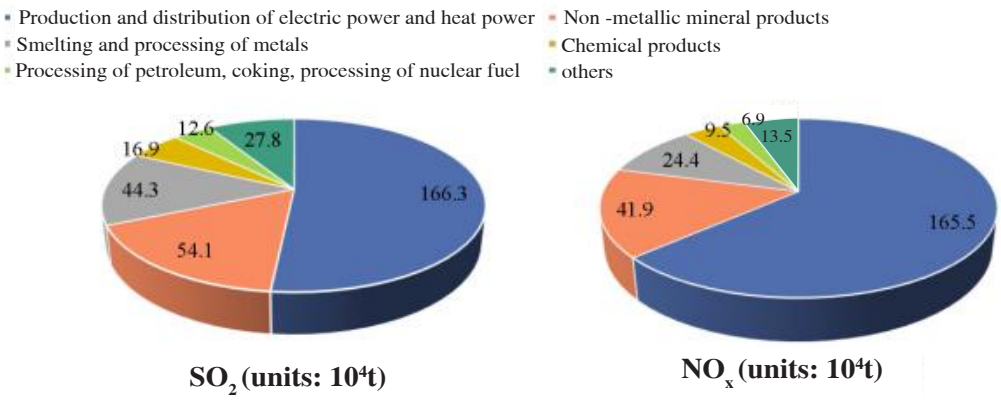
Table 7. The top five sectors of potential resource consumption (Water Plan)

Sectors	Coal/10^4 t	Sectors	Fresh Water/10^8 t
Production and distribution of electric power and heat power	31972.9	Production and distribution of electric power and heat power	150.3
Manufacture of non -metallic mineral products	6047.5	Smelting and processing of metals	17.8
Smelting and processing of metals	2282.0	Construction	15.9
Manufacture of chemical products	1510.2	Manufacture of chemical products	15.8
Processing of petroleum, coking, processing of nuclear fuel	265.0	Manufacture of non -metallic mineral products	10.2
Total	42077.7	Total	209.9

(2) Main pollutants emissions

During the implementation of the Water Plan, the additional SO_2 and NO_x emissions will be 3.22×10^6 t and 2.62×10^6 t, respectively. The *Production and distribution of electric power and heat power, Smelting and processing of metals,* and *Manufacture of non -metallic mineral products,* which together accounted for 82.2% and 88.6% of the additional emissions of SO_2 and NO_x respectively, are significantly higher than those in other sectors,

Figure 9. Emission of atmospheric pollutants (SO_2 and NO_x) by sector (Water Plan)

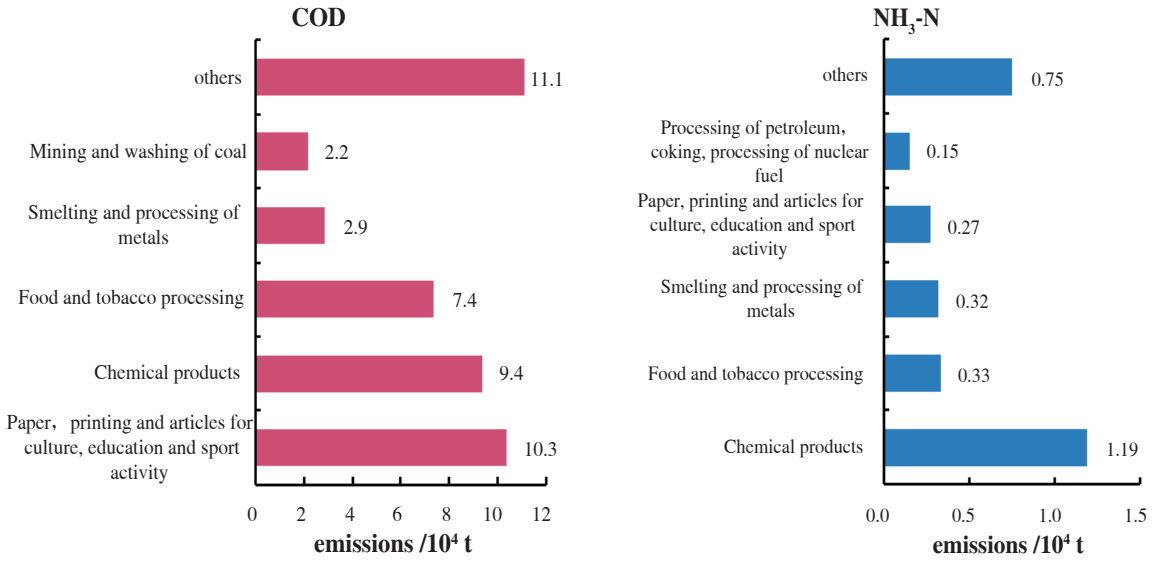


SO_2 (units: 10^4t)

NO_x (units: 10^4t)

On the other hand, the discharge of potential water pollutants will also increase, and the emissions of COD and NH_3-N will grow to 4.33×10^5 t and 3.03×10^4 t, respectively. In addition, three major industries, including *Manufacture of paper, printing and articles for culture, education and sport activity, Manufacture of chemical products, Food and tobacco processing* accounted for 62.6% of total additional COD emissions. *Manufacture of chemical products* will result in 1.19×10^4t of NH_3-N emissions.

Figure 10. Emission of wastewater pollutants (COD and NH_3-N) by sector (Water Plan)



4.3 The impacts of the Soil Plan on resource and environment

(1) Energy and Water

During the implementation of Soil Plan, the added coal and water consumption will be 8721.4×10^4t and 32.5×10^8t, respectively. The average annual additional consumptions are equivalent to 0.40% and 0.11% of their 2016 consumption. Potential coal and water consumption are mainly concentrated on *Production and distribution of electric power and heat power, Smelting and processing of metals, Manufacture of non -metallic mineral products, Manufacture of chemical products,* and *Construction* (see Table 8), which together accounted for 95% and 74% the additional resource consumptions.

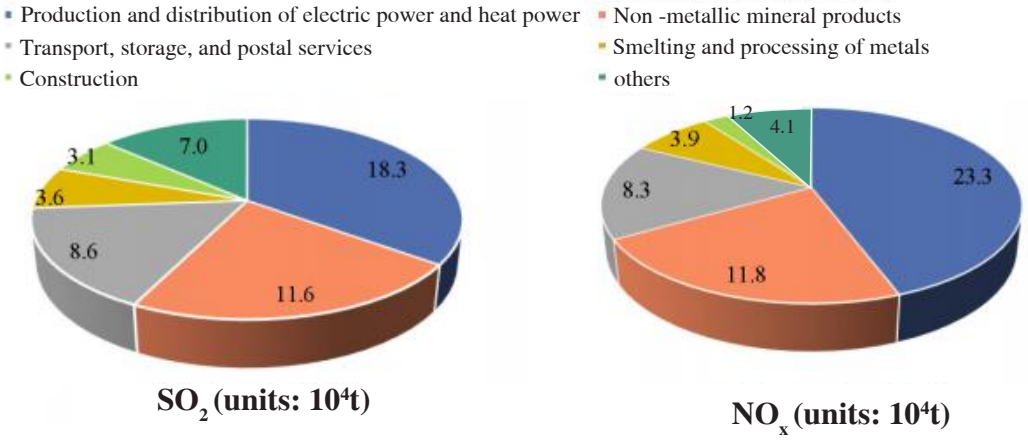
Table 8. The top five sectors of potential resource consumption (Soil Plan)

Sectors	Coal/10^4 t	Sectors	Fresh Water/10^8 t
Production and distribution of electric power and heat power	4147.3	Production and distribution of electric power and heat power	10.4
Manufacture of non -metallic mineral products	1380.3	Construction	4.7
Smelting and processing of metals	1352.8	Manufacture of chemical products	3.8
Processing of petroleum, coking, processing of nuclear fuel	837.1	Smelting and processing of metals	3.6
Manufacture of chemical products	585.7	Other services	1.6
Total	8303.1	Total	24.2

(2) Main pollutants emissions

During the implementation of the Soil Plan, additional SO_2 and NO_x emissions, amassing 5.20×10^5 t and 5.27×10^5 t, respectively, would be produced [16]. Several sectors, such as *Production and distribution of electric power and heat power, Smelting and processing of metals,* and *Manufacture of non -metallic mineral products* caused more SO_2 and NO_x emissions than others, accounting for 73.8% and 74.1% of total additional emissions of each pollutant, respectively (Figure 11). As illustrated in the 2015 Bulletin of National Environmental Statistics [17], the amount emissions of SO_2 and NO_x were 1859.1×10^4 t and 1851.9×10^4 t, respectively. During the implementation of the Soil Plan, additional SO_2 and NO_x emissions associated with Soil Plan were equivalent to 2.80%, 2.85% of yearly emissions in 2015, respectively. These statistics all pose serious ramifications for the atmospheric environment.

Figure 11. Emission of atmospheric pollutants (SO_2 and NO_x) by sector (Soil Plan)

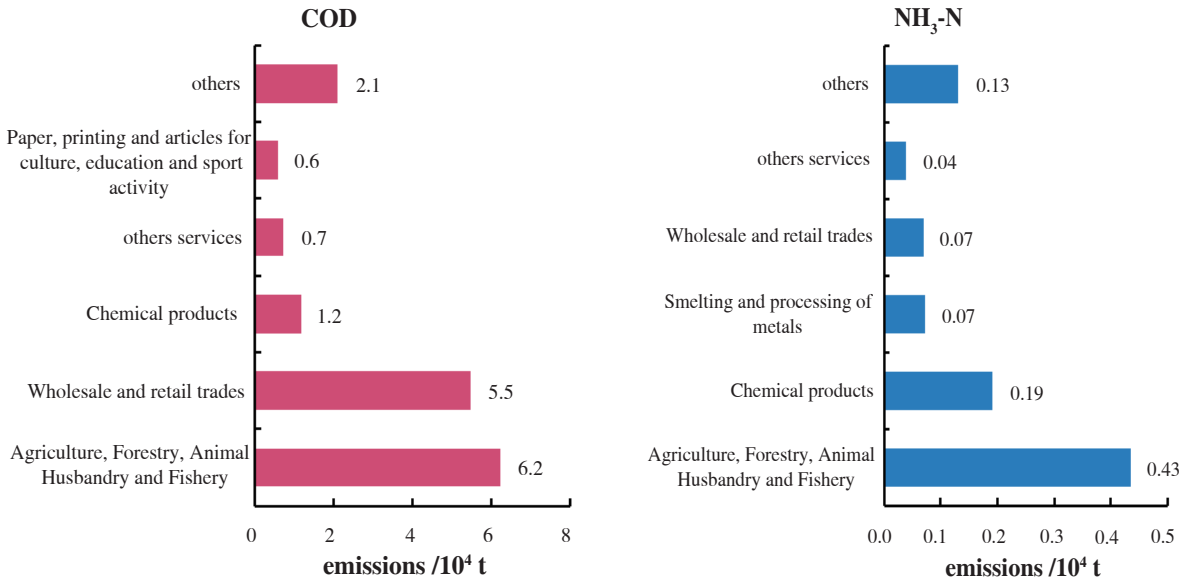


SO_2 (units: 10^4t)

NO_x (units: 10^4t)

On the other hand, the release of potential water pollutants was also predicted to increase during the Soil Plan's implementation period, with emissions of COD and NH_3-N rising by 1.62×10^5 t and 9.36×10^3 t, respectively. In addition, the *Agriculture, forestry, animal husbandry and fishing, Wholesale and retail trades,* and *Manufacture of chemical products* contributed a total of 79.1% and 74.3% of new COD and NH_3-N emissions, respectively (Figure 12). Moreover, the *Smelting and processing of metals* would cause 0.72 kt of new NH_3-N emissions. As illustrated in the 2015 Bulletin of National Environmental Statistics[17], the amount of emissions of COD and NH_3-N were 2223.5×10^4 t and 229.9×10^4 t, respectively. During the implementation of the Soil Plan, new COD and NH_3-N emissions were equivalent to 0.73% of yearly emissions in 2015, respectively.

Figure 12. Emission of wastewater pollutants (COD and NH_3-N) by sector (Soil Plan)



4.4 Summary

(1) Energy and Water

During the implementation of the three Plans (2013-2020), the cumulative added coal consumption will be 7.7×10^8t and three Action Plans (air, water and soil) account for 30.9%, 57.7%, and 11.4%, respectively. At the same time, the cumulative consumption of added water resources was 471.9×10^8t, and three Action Plans (air, water and soil) account for 33.4%, 59.7% and 6.9%, respectively. From sector level, potential coal consumption is mainly concentrated on the *Production and distribution of electric power and heat power, Manufacture of non -metallic*

mineral products, Smelting and processing of metals, Processing of petroleum, coking, processing of nuclear fuel, accounting for 95% of new coal consumption. On the other hand, almost 50% of water consumption is concentrated on *Production and distribution of electric power and heat power*, and the rest is mainly distributed into industries such as *Smelting and processing of metals, Manufacture of chemical products, Construction, and Mining* and *processing of metal ores.*

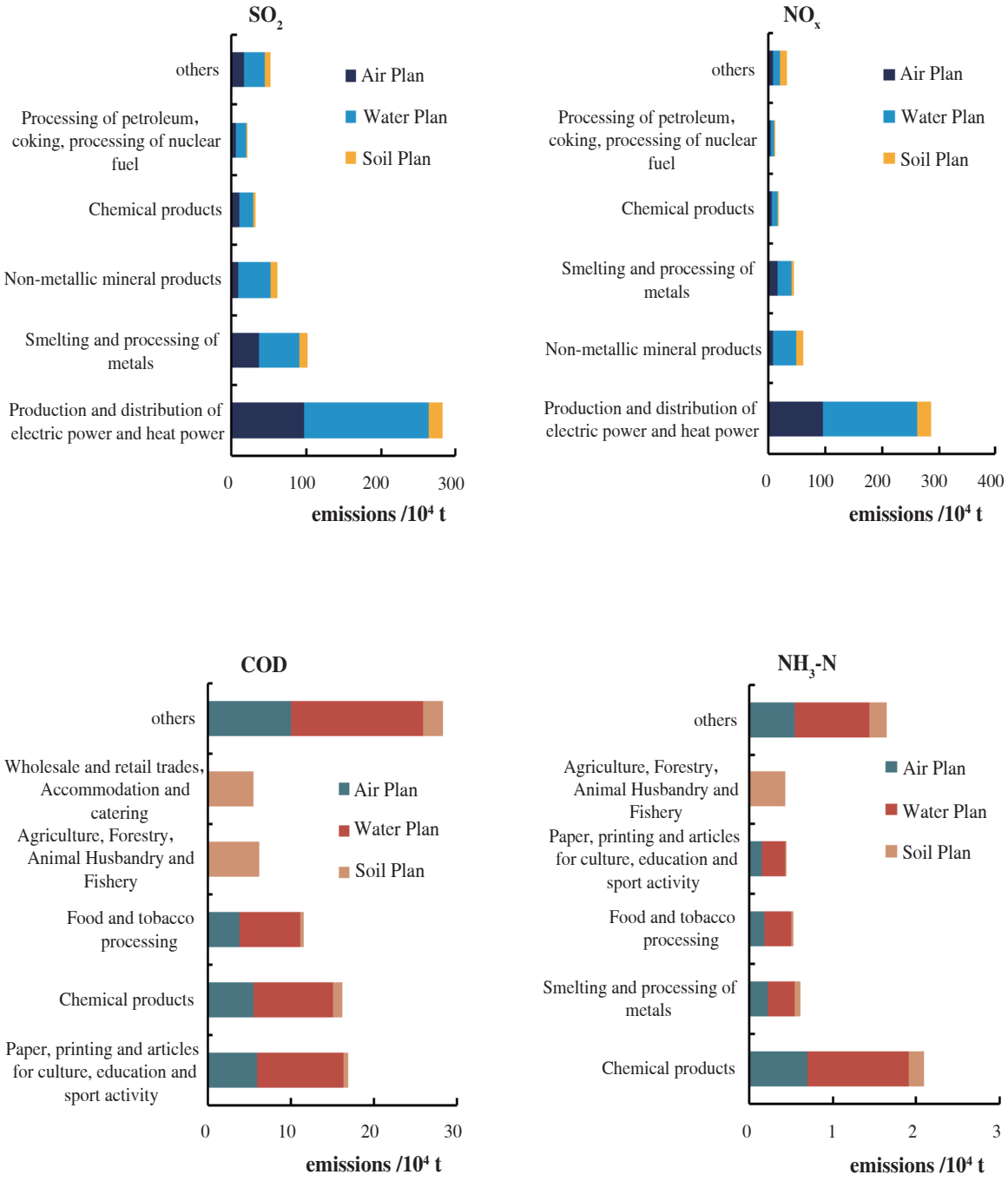
Table 9 The top five sectors of potential resource consumption

Sectors	Coal/10^4 t	Sectors	Fresh Water/10^8 t
Production and distribution of electric power and heat power	54910.4	Production and distribution of electric power and heat power	249.0
Manufacture of non -metallic mineral products	8566.3	Smelting and processing of metals	33.2
Smelting and processing of metals	5158.2	Manufacture of chemical products	32.0
Manufacture of chemical products	3136.7	Construction	22.0
Processing of petroleum, coking, processing of nuclear fuel	1234.3	Mining and processing of metal ores	16.5
Other sectors	3736.5	Other sectors	119.2
Total	76742.4	Total	471.9

(2) Main pollutants emissions

The potential pollution emissions of three plans will increase China 's SO_2 emissions by 5.50×10^6 t, and three Action Plans (air, water and soil) accounted for 32.0%, 58.6% and 9.5%, respectively. Additionally, the newly added NO_x emissions are 4.53×10^6 t, and three Action Plans (air, water and soil) accounted for 30.7%, 57.7% and 11.6%, respectively. In terms of atmospheric pollutants, *Production and distribution of electric power and heat power, Smelting and processing of metals, Manufacture of non-metallic mineral products, Manufacture of chemical products, Processing of petroleum, coking, processing of nuclear fuel* are five industries that affected most. The newly added SO_2 and NO_x emissions in these industries accounted for 90.4% and 92.7% respectively. Additional water pollutants are less than atmospheric pollutants. The implementation of the three Plans will increase China 's newly-added COD and NH_3-N emissions by 8.47×10^5 t and 5.75×10^4 t. In terms of water pollutants, *Manufacture of paper, printing and articles for culture, education and sport activity, Manufacture of chemical products, Food and tobacco processing, Agriculture, Forestry, Animal Husbandry and Fishery* are the most affected industries.

Figure 13. Additional emissions of four main pollutants by sector during implementation of three Action Plans



5. CONCLUSION

Our study shows that a total 8.05 trillion CNY is required for three Action Plans investment, which will lead to 11.16 trillion CNY additional GDP, and an input-output ratio of 1:1.4 in China, which indicates that it will not only effectively control pollution of air, water and soil, but also bring significant economic benefits. On the other hand, three Action Plans will indirectly consume more resources and bring more additional emissions through supply chains. During the implementation period, the cumulative additional coal and water consumption will be 7.7×10^8t, 471.9×10^8t, respectively; and three Plans will increase the emissions of SO_2, NO_x, COD and NH_3-N by 5.50×10^6 t, 4.53×10^6 t, 8.47×10^5 t and 5.75×10^4 t, respectively.

In this study, a closed macro input-output model was used to simulate the economic impact of the three action plans' investment. Our results were based on the following assumptions during the implementation: (1) The investments of three Action Plans would be solely used for the consumption of products; (2) The production technologies will remain unchanged during the implementation period; (3) The intensity of pollution discharge and resource consumption by sub-sectors will remain in year 2012's level. The above assumptions may overestimate our results.

It is important that the three action plans are primarily used as a means of improving China's environmental quality. Economic and environmental concerns, therefore, should not be the primary concern of investments. Furthermore, investment differs by region, as do the industrial structures of each individual province and city. Further study is needed to assess the economic and environmental impacts of investment in different regions. This would help provide appropriate policy recommendations for environmental protection in local regions.

REFERENCES:

1 Liu J.; Diamond J., Revolutionizing China's environmental protection[J]. Science,2008,319(5859):37-38.

2 Chan C.; Yao X., Air pollution in mega cities in China[J].Atmospheric Environment,2008,42(1):1-42.

3 He K.; Huo H.; Zhang Q., Urban air pollution in China: Current status, characteristics, and progress[J].Annual Review Of Energy and the Environment,2002,27:397-431.

4 Ma J.; Chen Y.; Wang W.; Yan P.; Liu H.; Yang S., et al. Strong air pollution causes widespread haze-clouds over China[J]. Journal of Geophysical Research: Atmospheres,2010,115(D18): D18204.

5 WHO, WHO Global Urban Ambient Air Pollution Database [DB/OL], 2012, http://www.who.int/phe/health_topics/outdoorair/databases/cities/en/

6 Ministry of Environmental Protection of China, China Environmental Quality Report[R]. Beijing, 2013. (in Chinese)

7 Ministry of Environmental Protection of China, China Environmental Quality Report[R]. Beijing, 2014. (in Chinese)

8 Li J.; Ma Y. B.; Hu H. W.; Wang J. T.; Liu Y. R.; He J. Z., Field-based evidence for consistent responses of bacterial communities to copper contamination in two contrasting agricultural soils[J]. Frontiers in microbiology, 2015, 6, 31.

9 Ministry of Ecology and Environment of PRC. The nationwide survey communique of soil pollution[R]. http://www.gov.cn/foot/site1/20140417/782bcb88840814ba158d01.pdf (in Chinese).

10 Du P.; Xie Y.; Wang S.; Zhao H.; Zhang Z.; Wu B.; Li F., Potential sources of and ecological risks from heavy metals in agricultural soils, Daye City, China[J]. Environmental Science and Pollution Research, 2015, 22, 3498-3507.

11 Miller, R. E.; Blair, P. D., Input-output analysis: foundations and extensions[M]. Cambridge university press: 2009.

12 Pasurka Jr, C. A., The short-run impact of environmental protection costs on US product prices[J]. Journal of Environmental Economics and Management, 1984, 11, 380-390.

13 Zhang W.; Wang J.; Jiang H.; Lei Y.; Bi J., Potential impacts of National Air Pollution Control Action Plan on economy and environment[J].Research of Environmental Sciences,2015,28(1): 1-7. (in Chinese)

14 Jiang H.; Zhang J.; Zhang W.; Hu X.; Lu Y.; Wang K., et al. Cost-benefit analysis of China's Three-year Plan on Defending the Blue Sky [R], Chinese Reference for Environmental Decision-making, 15(16): 1-42. (in Chinese)

15 Zhang W.; Wang J.; Jiang H.; Xu M.; Xu S.; W S., Potential impacts of National Water Pollution Control Action Plan on economy and environment[J]. Chinese Journal of Environmental Management. 2015,7(6):71-75. (in Chinese)

16 Li Z.; Wang J.; Li J.; Zhang W.; Liu R.; Song Z., et al. The Economic-Environmental Impacts of China's Action Plan for Soil Pollution Control[J], Sustainability, 11(8).

17 Ministry of Ecology and Environment of PRC, Bulletin of National Environmental Statistics in 2015[M]. China Statistics Press: Beijing, 2017. (in Chinese)

Appendix 1: The sectors in China's input-output table

Sectors		Sectors	
1	Agriculture, Forestry, Animal Husbandry and Fishery	22	Other manufacturing
2	Mining and washing of coal	23	Comprehensive use of waste resources
3	Extraction of petroleum and natural gas	24	Repair of metal products, machinery and equipment
4	Mining and processing of metal ores	25	Production and distribution of electric power and heat power
5	Mining and processing of nonmetal and other ores	26	Production and distribution of gas
6	Food and tobacco processing	27	Production and distribution of tap water
7	Textile	28	Construction
8	Manufacture of leather, fur, feather and related products	29	Wholesale and retail trades
9	Processing of timber and furniture	30	Transport, storage, and postal services
10	Manufacture of paper, printing and articles for culture, education and sport activity	31	Accommodation and catering
11	Processing of petroleum, coking, processing of nuclear fuel	32	Information transfer, software and information technology services
12	Manufacture of chemical products	33	Finance
13	Manufacture of non -metallic mineral products	34	Real estate
14	Smelting and processing of metals	35	Leasing and commercial services
15	Manufacture of metal products	36	Scientific research and polytechnic services
16	Manufacture of general purpose machinery	37	Administration of water, environment, and public facilities
17	Manufacture of special purpose machinery	38	Resident, repair and other services
18	Manufacture of transport equipment	39	Education
19	Manufacture of electrical machinery and equipment	40	Health care and social work
20	Manufacture of communication equipment, computers and other electronic equipment	41	Culture, sports, and entertainment
21	Manufacture of measuring instruments	42	Public administration, social insurance, and social organizations

Appendix 2: Environmentally Extended Input-output Framework [16]

The input-output model is a quantitative economic analysis method with which the technical and economic relationship between different sectors of the national economy, as well as each step of reproduction, can be scientifically analyzed against an input-output table. This model has been widely applied to analyze the impacts of large-scale infrastructure investment, government economic stimulus plan and environmental protection investments on macroeconomy. Economists have also used the model to analyze the effectiveness of environmental investments made in an attempt to fuel the economy. Additionally, resources and environmental input-output can also be simulated by inputting industrial pollution emissions and resource consumption data into the model, and evaluating the impact of environmental protection investment on resource consumption and emissions.

First developed by Leontief in 1970, the input-output model has been widely used across different fields: economic analyses, policy simulations, plan argumentation and economic forecasts. The calculations of economic impacts and emission contributions are based on environmentally extended input–output (IO) analysis. This well established method is the basis of the System of National Accounts and is well suited to the analysis of the economic and environmental impacts of the massive investment induced by Air, Water and Soil Plan. The *2012 China monetary Input-Output Table,* published by China's National Bureau of Statistics, was used as the input-output (IO) table for the present study. The table shows the structure of this IO table, which consisting of 42 sectors (listed in Appendix 1).

The structure of China monetary Input-Output Table used in this study

<table>
<tr><th colspan="2" rowspan="2">Input \ Output</th><th colspan="3">Intermediate use</th><th colspan="3">Final use</th><th rowspan="2">Imports</th><th rowspan="2">Total output</th></tr>
<tr><th>Sector 1</th><th>...</th><th>Sector 42</th><th>Final consumption</th><th>Capital formation</th><th>Exports</th></tr>
<tr><td rowspan="3">Intermediate inputs</td><td>Sector 1</td><td colspan="3" rowspan="3">X_{ij}</td><td colspan="3" rowspan="3">Y_j</td><td rowspan="3">IM_j</td><td rowspan="3">X_i</td></tr>
<tr><td>…</td></tr>
<tr><td>Sector 42</td></tr>
<tr><td rowspan="4">Value added</td><td>Employee compensation</td><td colspan="3" rowspan="4">G_{ij}</td><td colspan="5" rowspan="4"></td></tr>
<tr><td>Net taxes on production</td></tr>
<tr><td>Depreciation of fixed capital</td></tr>
<tr><td>Operating surplus</td></tr>
<tr><td colspan="2">Total inputs</td><td colspan="3">X_j</td><td colspan="5"></td></tr>
</table>

Assuming that a_{ij}, x_i, x_j and y_i represent the direct consumption coefficient, column vector and row vector of total output, and column vector of final demand, respectively, a transverse equation of input-output can be established as:

$$\sum a_{ij} \cdot x_j + y_i = x_i \quad (1)$$

Eq. 1 could be further expressed as a matrix equation:

$$X=(I-A)^{-1}Y \quad (2)$$

where the vector X (n×1 column) indicates each sector's total output (in CNY); the vector Y (n×1 column) indicates each sector's final demand; and the $n \times n$ matrix $(I-A)^{-1}$ is Leontief inverse matrix, which reflects the underlying relationship between final demand and total output. Changes in final demand (ΔY) would lead to changes in total output (ΔX), written as:

$$\Delta X=(I-A)^{-1}\Delta Y \quad (3)$$

The Soil Plan's investment projects were further divided into fixed capital formation and the consumption of goods and services, and classified according to different sectors. A column vector (ΔY_e) was then obtained and added into Eq. 3.

$$\Delta X=(I-A)^{-1}\Delta Y_e \quad (4)$$

More final demands resulting from investment during the Soil Plan leads to a rise in residents' consumption (income), again boosting various production sectors of China's national economy. However, the growth in residents' income cannot be completely converted into local investment and consumption, due to savings, taxes, and imports - resulting in an economic leakage. Therefore, it is necessary to establish a closed macro input-output model, excluding the impact of consumption growth and economic leakage. Using the derivation path proposed by previous research, the equation below can be obtained.

$$\Delta X = (I-A)^{-1}(I-C(1-t)\hat{h}Fi'\hat{W}(I-A)^{-1})^{-1}\Delta Y_e \quad (5)$$

C represents the marginal propensity to consume (to deduct the effect of consumption leakage); t represents the marginal propensity to tax (to deduct the effects of tax paid); $\hat{h}$ represents the diagonal matrix of domestic availability rates of final products (to deduct the effects of import leakage); F represents the column vector of residents' direct consumption coefficients, i' represents the unit row vector, and $\hat{W}$ represents the diagonal matrix of compensation coefficients. Domestic availability rates of final products illustrate the proportion of domestic products to final products in various sectors; residents' direct consumption coefficients refer to the proportion of residents' consumption in various sectors to residents' total consumption; and compensation coefficients refer to coefficients of compensation in various sectors divided by total output.

Economic impact evaluation. Adding a row vector of economic growth coefficients $(\hat{G})$ and a row vector of input coefficients of labor force $(\hat{J})$ into Eq. 5, GDP growth (ΔG) and employment positions (ΔJ) can be described

respectively as:

$$\Delta G=\hat{G}\Delta X \quad (6)$$

$$\Delta J=\hat{J}\Delta X \quad (7)$$

The economic growth coefficient for a sector is the ratio of economic growth to total output; the input coefficient of the labor force for a sector is the ratio of employment positions to total output. Economic growth of all sectors can be directly obtained from the third quadrant of the input-output table. All the employment data has been taken from the *2017 China Labour Statistical Yearbook.*

Environmental impact evaluation. Adding a row vector of emission intensity *($\hat{S}$)* into Eq. 5, the growth in emissions (ΔS) of typical pollutants (SO_2, NO_x, COD and NH_3-N) can be described as:

$$\Delta S=\hat{S}\Delta X \quad (8)$$

Emission data of these four typical pollutants across various sectors were taken from the *2012 China Environmental Statistics.*

CAEP Scientific Research Platforms

- Center for Emission Trading
- Center for Ecological Environmental Compensation
- Center for Environmental Research on Beijing-Tianjin-Hebei Region
- Center for Heavy Metal Pollution Prevention
- Center for Climate Change and Environmental Policy
- Center for Environment and Health
- Center for Environmental Zoning
- Center for Ecological Environment in Yangtze River Economic Zone
- Center for Environmental PPP
- Center for Environmental Protection Tax
- Center for Investment Performance Management
- Center for Ecological Environment and Economic Accounting
- Center for Rural Environmental Protection
- Center for Regional Air Quality Simulation and Control
- Center for Environmental Auditing
- Center for Marine Eco-environmental Planning
- Center for Environmental Decision-making and Performance Assessment
- Center for Yellow River Eco-civilization

Chinese Academy of Environmental Planning

8 Dayangfang, BeiYuan Road, Chaoyang District, Beijing 100012, China

Editor in chief: Prof. WANG Jinnan

President, Chinese Academy of Environmental Planning

Contact person: Mr. ZHANG Hongyu

Tel: 86-10-84917585

Fax: 86-10-84918581

E-mail: zhanghongyu@caep.org.cn

Web: www.caep.org.cn